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BUREAU OF PLANT INDUSTRY—BULLETIN NO. 125.
B. T. GALLOWAY, *Chief of Bureau.*

DRY-LAND OLIVE CULTURE IN NORTHERN AFRICA.

BY

THOMAS H. KEARNEY,

PHYSIOLOGIST IN CHARGE OF ALKALI AND DROUGHT RESISTANT PLANT-BREEDING INVESTIGATIONS.

ISSUED APRIL 11, 1908.

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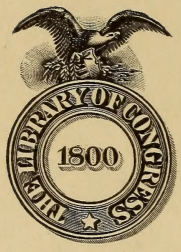

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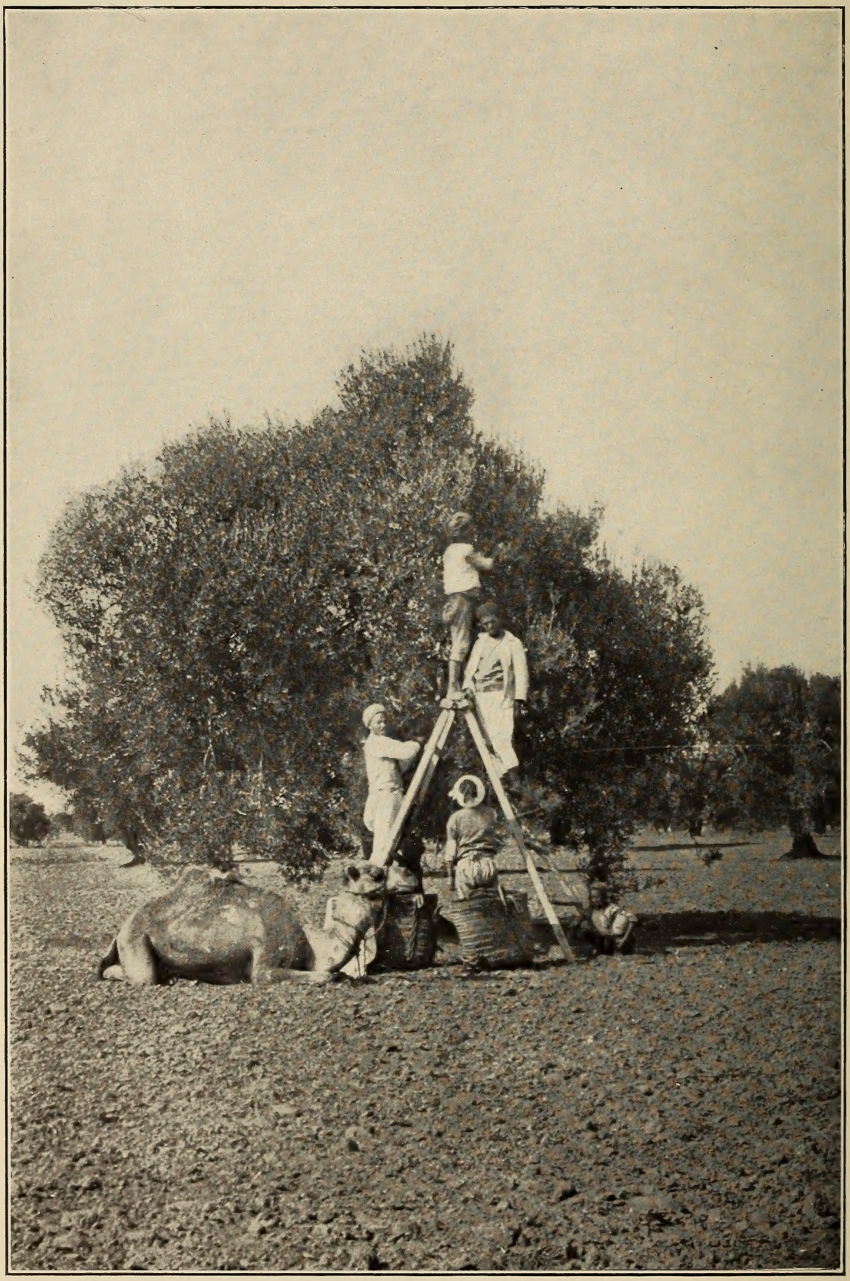

HARVESTING CHEMLALY OLIVES IN A DRY-LAND ORCHARD AT SFAX.

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BUREAU OF PLANT INDUSTRY—BULLETIN NO. 125.
B. T. GALLOWAY, *Chief of Bureau.*

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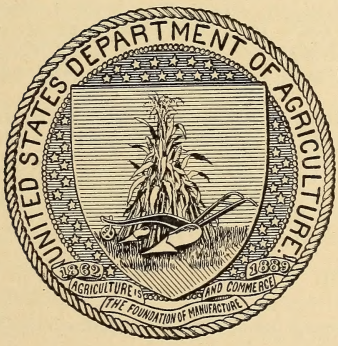

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Thomas H. Kearney, *Physiologist in Charge.*

L. L. Harter, *Assistant Physiologist.*

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., January 5, 1908.

Sir: I have the honor to transmit herewith and to recommend for publication as Bulletin No. 125 of the series of this Bureau the accompanying manuscript, entitled "Dry-Land Olive Culture in Northern Africa."

The culture of the olive without irrigation in a region where the average yearly rainfall is only 9.3 inches is the most highly successful example of dry-farming methods applied to a tree crop of which we have any knowledge. It has long passed the experimental stage, having been carried on in southern Tunis with the methods now in use for at least fifty years and having been developed on a vastly more extensive scale in the same region during the early centuries of the Christian era.

The description here given of the methods and of the type of tree adapted to this system of culture will be of special interest to that portion of the southwestern United States where olive culture is possible. But it also concerns arid and semiarid regions outside of the olive zone where arboriculture, based upon other crops, seems destined to become an important feature in dry-land agriculture. The present paper should stimulate the search for useful trees capable of being grown profitably under dry-farming conditions.

In the course of an expedition to Tunis for the Office of Seed and Plant Introduction and Distribution, the primary object of which was to obtain promising varieties of dates for trial in the southwestern United States, Mr. Kearney spent several weeks in the dry-land olive-growing districts studying the methods used and the conditions under which the culture is there carried on. This was done at the suggestion of Mr. W. T. Swingle, of this Bureau, who has charge of investigations in dry-land arboriculture.

The drought-resistant variety of the olive that is grown in Tunis has been introduced with a view to establishing dry-land olive culture in the United States. Investigations along this line will be carried

on in cooperation between the offices of Plant Life History Investigations and of Alkali and Drought Resistant Plant Breeding Investigations.

Acknowledgment is here made of the valuable assistance rendered Mr. Kearney in the course of his investigations by the Tunisian authorities and by private individuals interested in olive culture. Mention should be made of the courtesies extended by M. Fidelle, late controleur civil at Sfax; M. Minangoin, inspector of agriculture in the Direction of Agriculture and Commerce at Tunis; Mr. Leonardi, British vice-consul at Sfax; M. Robert, president of the chamber of commerce at Susa; and MM. Louis Fidelle and A. Chatel, olive growers at Sfax.

The illustrations which accompany this paper are considered essential to a full understanding of the text.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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DRY-LAND OLIVE CULTURE IN NORTHERN AFRICA.

INTRODUCTION.

A great awakening to the possibilities of dry-land agriculture has recently taken place in the western United States. Land is being rapidly taken up and brought under the plow, largely by eastern farmers, in regions where the average yearly rainfall does not exceed 18 inches and where water is not available for irrigation. The unusually heavy rainfall of the past few seasons has allowed many of the newcomers to obtain good crops of small grain and forage under these conditions; but the recent recruit to "dry farming" must not lose sight of the fact that such periods of unusually heavy rainfall are sure to be followed sooner or later by periods of drought, when the plants ordinarily grown in humid regions will give him but uncertain results. To insure against disaster he should be on the lookout for drought-resisting varieties of the crop plants he is familiar with or else for new crop plants adapted to arid conditions.

No class of plants is more resistant to drought than certain trees and shrubs, some of which are extremely useful in countries having a climate similar to that of the Great Plains and Great Basin regions of the United States. Arboriculture (tree culture) is one of the safest and most promising lines along which dry-land agriculture can develop. Experience in various parts of the Old World has shown that drought-resisting trees will live and will often produce a crop in years when no shallow-rooted annual crop will return the seed sown.

The most highly developed and successful example of dry-land arboriculture known to the writer is based on the olive, a tree that is peculiarly well fitted for growing under arid conditions. Its leaves are protected against excessive loss of water by the thick skin or cuticle of the upper surface and by the scurf of scale-like hairs with which the under side is covered. Its root system is of such a nature as to permit it to grow without irrigation in regions where the rainfall is scanty and the ground water is practically out of

reach. The roots of the olive run for long distances comparatively close to the surface of the soil, and are thus able to take up the moisture that penetrates a few inches into the ground after every moderate rainfall. The unusual hardiness of this tree is shown by the fact that in many localities in northern Africa where it was once planted it has persisted for centuries without receiving any attention, often running wild and mingling with the native trees and shrubs on the driest hillsides.

Fifteen hundred years ago southern Tunis was covered with thriving olive orchards, but these gradually disappeared after the country was conquered by the Arabs, so that at the beginning of the last century olive culture had almost died out in that region. A good beginning has since been made in reestablishing it, and to-day the dry-land orchards of southeastern Tunis are the wonder and admiration of olive growers the world over.

A description of this model arboriculture, of the climatic and soil conditions under which it is carried on, and of the methods used and the results obtained can hardly fail to interest those who are concerned in dry-land agriculture. It is true that in the United States the olive can be a profitable crop only in the warmer parts of the arid and semiarid districts, i. e., in southern and western Texas, in southern Arizona, and in California. But there are other drought-resistant trees that are better able to withstand cold and can therefore be grown to advantage farther north. Some of these, although not yet well known in the United States, are of great importance in various parts of the world, being grown either for their fruit, for forage, or for timber and fuel. In the drier parts of Europe and Asia there are varieties of our common orchard trees that would probably give better results under dry farming conditions than the varieties ordinarily grown in the humid parts of the United States or under irrigation in the West. An account of dry-land olive culture in Tunis should therefore be useful even outside the olive zone, as it will direct attention to the type of tree and the methods of culture that are likely to give the best results.

IMPORTANCE OF DRY-LAND ARBORICULTURE IN ANCIENT AFRICA.

Southern Tunis is to-day an arid, treeless waste, almost a desert, covered with a sparse growth of thorny bushes and coarse bunch-grasses. There are no streams of considerable size to furnish water for irrigation, and the average yearly rainfall is small, ranging from 8 to 14 inches. In many places a fair crop of wheat or barley can be expected only once in three or four years. This region is now uninhabited, save by a few thousand Bedouins, who wander from

place to place in search of pasturage for their sheep and goats. Except on the coast and at a few points near the mountains along the northern and western borders of the district there are no large towns and hardly any permanent villages. The desolation is almost everywhere complete.

Yet during the third to the seventh century of the Christian era this whole district (fig. 1), from the seacoast westward into what is now eastern Algeria, was thickly dotted with thriving villages and farms. In an area not exceeding 20,000 square miles—15,000 within the boundaries of modern Tunis and perhaps 5,000 in Algeria—there were at least a dozen cities of 10,000 to 30,000 inhabitants. A network of splendid paved roads, such as the Romans knew so well how to build, connected these cities with each other and with those of the seacoast. While in the height of its prosperity, that part of the region belonging to what we now call

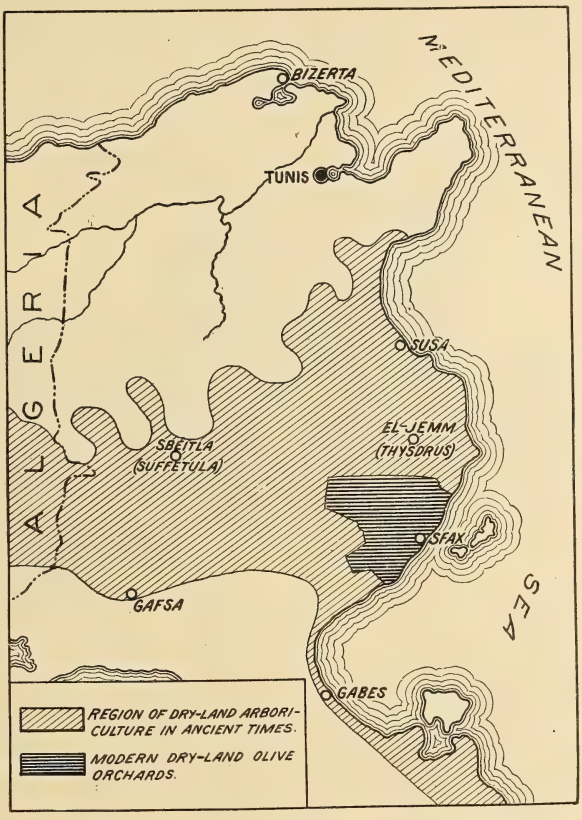


FIG. 1.—Map of Tunis,[a] showing the probable extent of the dry-land arboricultural region in ancient times and the area now occupied by dry-land olive orchards. (After Bourde.)

[a] The northeastern portion of the lightly shaded area, at least near the seacoast, is not typical of the dry-land arboricultural region, the yearly rainfall at Susa averaging 16.6 inches. In the southeastern portion (below Gabes) it is unlikely that the dry-land orchards extended as far from the coast as is indicated on the map. In the absence of exact data for correction, however, it seems best to follow the limits of the region as traced by Bourde (Rapport sur les Cultures Fruitières, etc., Tunis, 1899).

Tunis, of which it formed about one-third, had a population of at least 1,500,000, or about the present population of the whole of Tunis.

The flourishing state of this part of Africa in former times is abundantly attested, not only by the statements of Arab writers who saw the country before it had completely relapsed into its present desolation, but by the ruins that are strewn over it in such numbers that one can hardly ride for half a mile without encountering some fragment of an ancient building, or cistern, or reservoir. The public buildings of the cities had a degree of architectural merit which shows that the ancient inhabitants enjoyed not merely prosperity, but wealth and luxury. The inscriptions prove that some of the finest of these structures were built not by the government or the municipality but by private citizens inspired by local pride, which was kept alive by the keen rivalry that existed among the towns of Roman Africa.

We need mention only two examples of the splendid development of this country in Roman times. In an area of 100 square miles around the ancient city of Suffetula (fig. 1) there have been found the remains of 3 cities, 15 towns, and 45 small villages, besides almost innumerable scattered farm buildings. Near the seacoast, on the site of the ancient city of Thysdrus (fig. 1), stands a great amphitheater which is second in size only to the Colosseum at Rome and is estimated to have seated 60,000 people. But the Roman city which it adorned has given place to a squalid Arab village huddled under the walls of the amphitheater, while around it in every direction stretches a bare, uncultivated plain. How can we account for the existence of the 60,000 souls that crowded the amphitheater of Thysdrus on festival days to view the sports of the arena? How did the teeming population of Suffetula support itself and accumulate wealth sufficient to build the beautiful marble temples and baths and theaters that adorned the city in the early centuries of the Christian era?

All the evidence goes to show that the climate has not changed materially and that the rainfall has not diminished since Roman times. We have no reason to believe that the country was formerly better watered or that agriculture based upon irrigation could ever have reached a high development in that part of Africa. The remains of innumerable cisterns lined with masonry or concrete—more than 400 have been counted in one small district near Sfax alone—prove that the inhabitants had to depend for domestic purposes upon stored rain water. Some of the larger cities had public cisterns of gigantic size. Even near the mountains it was necessary to utilize every spring and to build long aqueducts to carry water to the cities and towns. There could have been little to spare for agricultural purposes, except, perhaps, to irrigate the gardens immediately around the towns.

The gnarled old olive trees that are found here and there over the country (fig. 2), often standing in straight rows just as they were planted centuries ago,[a] and the almost innumerable ruins of oil mills answer our questions. The remains of more than a thousand oil mills are said to exist in the hundred square miles around Suffetula alone. They were built of stone and were often of imposing size. In many places the stone basins in which the fruit was crushed and the perforated stone pillars that supported the bar of the press are still to be seen.

FIG. 2.—An olive tree, probably several centuries old, growing without irrigation in Algeria.

If we turn to the Roman and Arabic historians and geographers, we find abundant evidence that the wealth of this part of Africa was based upon dry-land tree culture on a vast scale.[b] The olive was undoubtedly the chief source of these riches, although other more or less drought-resistant trees, such as the pistache, fig, and almond, doubtless played an important part. It has been calculated that the olive orchards of southern Tunis covered 2,500,000 acres when the Arabs conquered the country, about 700 A. D. Ancient Rome, which consumed an enormous quantity of olive oil, drew its supply largely from this region. Under the Cæsars the province of Africa, which comprised the same territory as modern Tunis, was taxed 300,000 gallons yearly for the benefit of the capital.[c] So important

[a] Olive trees several hundred years old are frequently met with in Algeria and Tunis. In many places the existing trees are offshoots that have sprung up from the roots of older ones, the original trunk having long since disappeared.

[b] This view was first advanced in a convincing form, with an admirable summing up of the historical and archæological evidence, by P. Bourde, at one time Director of Agriculture in Tunis, in a little pamphlet entitled "Rapport sur les Cultures Fruitières et en Particulier sur la Culture de l'Olivier dans le Centre de la Tunisie." (Report on Fruit Culture and Especially Olive Culture in Central Tunis.) Tunis, 1892; 2d edition, 1899.

[c] Graham, Alexander. Roman Africa, London, 1902, p. 57.

was this article in the ancient commerce of the country that, as the local tradition has it, one of the cities near the eastern coast built a conduit solely for the purpose of transporting oil to its seaport.

The Arab invaders, being a pastoral and not an agricultural people, are said to have wantonly destroyed the olive orchards in order to create pastures for their flocks. More probably the orchards gradually died out from neglect, large numbers of the original inhabitants of the country having been killed or driven from their farms by the invaders, who neither knew nor cared anything about tree culture. During the centuries that followed, the country was in too turbulent a state to make a restoration of the olive orchards possible. Moreover, the decline of Rome and the destruction of commerce on the Mediterranean put an end to the foreign trade in oil and left Tunis without a market for its surplus production.

However this may be, only mere fragments of this magnificent forest of olives remain to-day in southern Tunis. In the northern part of the country, where the rainfall is much greater and the trees can exist without the use of special cultural methods to conserve moisture in the soil, olive growing has continued without interruption down to the present time.

DRY-LAND OLIVE CULTURE IN MODERN TUNIS.

At a few points along the coast in central and southern Tunis the orchards never disappeared entirely, and within the last century a notable effort has been made to reestablish the ancient condition of things in the neighborhood of Sfax, a thriving seaport on the eastern coast (fig. 1). The work was begun by the inhabitants on their own initiative, hesitatingly and inefficiently at first. About 1840 the system of planting and of tillage now in use was introduced or revived [a] by one of the more intelligent natives, and from that time the progress was rapid. When the French occupied Sfax in 1881 the orchards already covered 45,000 acres, and up to that time Europeans had had no part in the work.

During the last twenty years most of the new orchards have been created by French capitalists, although native laborers have been almost exclusively employed and the cultural methods are essentially those in use before the country was occupied by Europeans. Be-

[a] In all probability the system of wide spacing of the trees and thorough tillage is not a recent invention, but was in use by the Romans more than 1,500 years ago. These practices, or at least the tradition of them, doubtless continued to exist in the region through all the centuries of the Arab domination, to be brought once more into general use during the past century.

tween 1892 and 1904 French stock companies and individual colonists purchased from the Tunisian government 200,000 acres of public land and planted more than one and a half million olive trees, besides a large number of almonds. These lands are sold by the government at the rate of 75 cents an acre, one-half of the price being payable in advance and the remainder within four years, on condition that the purchaser shall put the land into a tree crop before the end of that time. This is in pursuance of the policy of the government to encourage in every possible way the restoration of the olive orchards that made the country prosperous in ancient times.

At present the orchards extend without interruption to an average distance of 20 to 25 miles from Sfax, while some of the outlying plantations are as much as 40 miles distant from the town. Those within a radius of 12 miles from Sfax, which are now in full bearing, belong almost exclusively to natives, while beyond them are the plantations of young trees more recently established by French colonists. These newer orchards are in nearly all cases very large, some of them containing more than 25,000 trees. The entire area around Sfax occupied by dry-land olive orchards was estimated in 1900 to be 475,000 acres, containing 3,333,000 trees. During the ten years from 1896 to 1905 a yearly average of more than 1,000,000 gallons of oil was produced. The product of these orchards is sufficient to maintain about two dozen oil mills in the town of Sfax, operated by Europeans and equipped with modern machinery, besides twice as many native mills, in which the power is furnished by animals.

This wide expanse of orchards is a most impressive sight. The best view of it (see Pl. IV, fig. 1) is to be had from the summit of a little hill about 10 miles northwest of Sfax to which all visitors are taken. The straight rows of trees, separated by broad bands of bare, reddish soil, stretch to the horizon in almost every direction. The whole face of the country is striped with gray-green and red. Probably nowhere else in the world has olive culture been so highly developed. The regularity of the planting is striking to anyone who is familiar with the haphazard way in which the trees are set out on hillsides in most parts of the Mediterranean region.[a] The trees stand in perfectly straight lines and are 65 to 80 feet apart in each direction. They are carefully trimmed so as to have a symmetrical, square-topped spread of foliage and are remarkably uni-

[a] The jury for olive culture of the Congress held at Tunis in 1888, which was composed largely of French olive growers, agreed that the plantations at Sfax are "superb and leave far behind anything to be seen in Europe as to development of the trees and quantity of the fruit." At that time the orchards were still practically all in the hands of natives.

form in size and shape. Nothing else is grown among them after they begin to bear, and the cultivation is so clean that it is hard to find a blade of grass in the well-cared-for orchards.

This admirable culture is carried on without irrigation in a region where the rainfall averages only 9.3 inches and sometimes falls as low as 6 inches during several successive years. It is the most successful example of dry farming applied to a tree crop of which we have any knowledge.

In order to understand the cultural methods practiced, it is necessary first of all to know something of the physical conditions of the Sfax region.

GENERAL CHARACTERISTICS OF THE SFAX REGION.

CLIMATE.

Sfax, like most localities in northern Africa, has many of the climatic peculiarities of the vast Sahara Desert, which practically reaches the sea near the border of Tripoli, 110 miles southeast of Sfax. For this reason the climate of the east coast of Tunis, even as far north as the city of Tunis (fig. 1) is much more desert-like than the coast of Algeria, which is separated from the Sahara by two ranges of mountains. At Sfax the chief points in which the climate approaches that of the desert are the small rainfall and the long, hot summers. Yet it is not a typical desert climate, for the neighborhood of the sea gives it a comparatively high relative humidity and smaller daily and seasonal ranges of temperature than those that characterize the Sahara itself.

Table I shows the average monthly temperatures at Sfax:

TABLE I.—*Monthly and annual average mean, mean maximum, and mean minimum temperatures at Sfax, in degrees Fahrenheit.*[a]

Month.	Mean.	Mean of the maxima.	Mean of the minima.
	°F.	°F.	°F.
January	51.3	59.1	43.3
February	54.4	61.8	46.9
March	59.1	67.2	50.2
April	63.2	72.1	54.9
May	68.8	77.5	60.5
June	72.8	80.9	65.9
July	78.5	87.8	72.0
August	79.3	88.1	72.9
September	78.4	86.6	73.2
October	72.8	79.4	64.5
November	61.8	69.1	53.7
December	54.0	62.5	45.8
Annual mean	66.2	74.3	58.6

[a] The monthly means for Sfax are based upon records covering a period that varies in length for different months from eight to seventeen years, but they have been corrected so as to agree with the sixteen-year means for each season (winter, spring, summer, and autumn) given by G. Ginestous (Etude sur le Climat de la Tunisie, Bul. Dir. Agric. et Com. Tunis, 1902 and 1903). The correction in most cases amounts to only about 1° F. and in no case exceeds 3°.

Most localities in the southwestern portion of the United States are characterized by a greater range of temperature than occurs at Sfax, having colder winters and warmer summers. At Tucson, Ariz., the monthly mean temperatures are much like those at Sfax, except for May, June, July, and August, when the temperatures are considerably higher at Tucson. The means of the maxima of the spring and summer months are much higher at Tucson than at Sfax, while the means of the minima are much lower at Tucson during the nine months from September to May. The yearly mean of the maxima is nearly 8 degrees higher, and the yearly mean of the minima is 6½ degrees lower at Tucson than at Sfax.

San Antonio, Tex., corresponds closely with Sfax in the mean temperatures of all the months, except April, May, and June, when the monthly means are considerably higher at San Antonio. The monthly means of the maxima are uniformly somewhat higher at San Antonio, the difference being most marked for the months of April to July. The monthly means of the minima at San Antonio are slightly lower in autumn and winter but somewhat higher in spring and summer than at Sfax.

There is no evidence, however, that within wide limits temperature is a factor of very great importance in olive culture.

Table II shows the average monthly and annual precipitation at Sfax:

TABLE II.—*Average monthly and annual precipitation at Sfax.*[a]

Month.	Precipitation.	Month.	Precipitation.
	Inches.		*Inches.*
January	0.97	August	0.04
February	1.17	September	0.78
March	0.70	October	1.17
April	1.25	November	1.21
May	0.58	December	1.36
June	0.08		
July	0.04	Total annual	9.35

[a] Based upon a period of fifteen years (1886 to 1900). The above data are taken from G. Ginestous, Les Pluies en Tunisie, Dir. Gén. de l'Enseignm. Publ., Serv. Météorol., ed. 2, pp.. 86, 87 (1901).

If we compare the rainfall of Sfax with that of localities in the southwestern United States, we find that San Diego and Fresno, Cal., Tucson, Ariz., and El Paso, Tex., have practically the same yearly total, while at San Antonio, Tex., the yearly total is about three times as great, and at St. George, Utah, only about two-thirds as great. In the distribution of the rainfall during the different months of the year, San Diego and Fresno most nearly resemble Sfax, while Tucson, El Paso, and San Antonio show a marked difference in their relatively heavy midsummer rainfall. Most of the precipitation at Sfax occurs in the autumn, winter, and early spring,

December being the month of greatest rainfall, with a second maximum, only slightly lower, in April. July and August are the driest months.

The total rainfall at Sfax varies greatly in different years. Thus, in 1890 it amounted to 17.4 inches, and in 1895 it was only 3.2 inches. During the seven years from 1898 to 1904 the total rainfall was only 41 inches; hence the yearly average was only 5.8 inches. The relation that apparently exists between the rainfall and the size of the olive crop is discussed farther on.

There are no perennial streams in the Sfax region. The inhabitants depend upon wells and cisterns for water for irrigating their gardens and newly set out olive trees as well as for household purposes. The wells vary greatly in depth. For instance, about 30 miles north of the town there is a well 220 feet deep, while only 3½ miles away there is a 33-foot well. The average depth is perhaps between 50 and 80 feet.

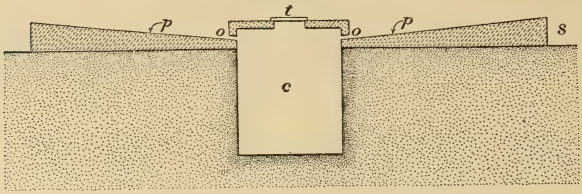


FIG. 3.—Diagram showing construction of cisterns at Sfax, being a section through two of the openings (*o*) in the concrete cover (*t*) by means of which water that falls upon the platform (*p*) enters the cistern (*c*); *s* is the surface of the soil.

In the zone of gardens containing a variety of fruit trees which lies between the town and the olive orchards, the roads are bordered by cisterns of a peculiar type (fig. 3). A concrete platform, often 40 or 50 feet square and about 2 feet high at the edge, slopes from all sides toward the center, the opening of which is protected by a concrete cover. Small holes in the sides of the cover allow the water that falls upon the platform to enter the cistern beneath. Water is drawn when needed through a hole in the top of the cover, which is protected by a movable lid. This type of cistern has been used in Tunis for two thousand years or more.

In years of unusually small rainfall, such as 1904, water becomes so scarce that 4 or 5 gallons (the capacity of the ordinary water jar used by the natives) are retailed for 2 cents. It has been necessary at times to import drinking water from Naples and to use sea water for washing clothes.

TOPOGRAPHY AND SOILS.

TOPOGRAPHY AND NATURAL VEGETATION.

The portion of southern Tunis in which dry-land olive culture reached its highest development in ancient times is that where Quaternary deposits form the surface covering. The district around Sfax that is now occupied by olive orchards is a slightly rolling plain of low elevation, extending from the coast toward the base of the high table-land that occupies central Tunis. In its natural condition it is a steppe, in many ways like the great plains east of the Rocky Mountains, and especially like parts of western Texas and eastern New Mexico. It bears a scattered vegetation, a conspicuous feature of which is the Christ thorn (*Zizyphus spina-christi*), a spreading thorny bush with most of the trunk underground, thus resembling the mesquite (*Prosopis juliflora*) as it grows in eastern New Mexico. Like the mesquite, the Christ thorn generally occupies the summits of small mounds, which it has probably helped to form by catching and holding wind-blown soil. While its stems are usually only 4 or 5 feet high above ground, its roots are said often to penetrate to a depth of 12 feet or more. The presence of this shrub makes the clearing of the land difficult and expensive. Sagebrush (a species of Artemisia) and coarse bunch-grass make up the bulk of the natural vegetation.

SOILS.

The soil that is considered most desirable for olive culture is bright red in color. It is generally of considerable depth, but at some places within 20 miles of Sfax hardpan is said to be encountered only 24 inches below the surface. To an average depth of 7 feet the soil appears to be generally rather uniform in texture, but below this strata of fine material alternate with layers of coarse sand and gravel. As regards water content, it is stated [a] that when the surface soil was air dry, at a depth of 8 inches the moisture content was found to be 6 per cent, at 20 inches 10 per cent, and at 40 inches 14 per cent. This would indicate a distribution of soil moisture to which only trees and deep-rooted perennials could adapt themselves. It is said [b] that even after several months without rain the soil at a depth of 8 inches contains enough moisture to stick together when squeezed in the hand. At the end of January, 1905, however, when heavy rains had followed a prolonged drought, the writer observed that while the

[a] Bourde, P. Rapport sur les Cultures Fruitières * * * dans le Centre de la Tunisie, 2d edition, 1899, pp. 13, 14.

[b] Bertainchand. Note Explicative sur la Carte Agronomique et Hydrologique * * * des Terres de la Région de Sfax, Paris, 1896, p. 16.

first 8 inches of the soil had been thoroughly moistened the next 16 to 24 inches were very dry and powdery.

As to texture, this soil when dry has the appearance of a sandy loam, with rather coarse particles. An average of the results of mechanical analyses by the chemist of the Tunisian government [a] of 82 samples collected in every part of the Sfax region gives 80 per cent of "coarse sand" and 20 per cent of "fine material." Yet an apparently typical sample collected by the writer in an olive orchard about 5 miles from Sfax was found by the Bureau of Soils of the United States Department of Agriculture to contain a great deal of silt and clay, amounting together in the surface foot to 45 per cent of the whole and in the third foot to 23 per cent. The remaining 55 and 77 per cent, respectively, consisted mainly of "fine sand" and "very fine sand." The real state of the case appears to be that in the natural condition of the soil these fine particles are held together by lime or some other cementing material, so as to form particles that resemble grains of coarse sand. These become separated when the soil is shaken for a long time in water.[b]

Table III shows the results of mechanical analyses made by the Bureau of Soils of the United States Department of Agriculture of soil samples from the Sfax olive orchards.

TABLE III.—*Mechanical analyses of soil samples from the olive orchards of Sfax.*

Locality.	Depth taken.	Fine gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0 mm.
	Inches.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Olive orchard, Sfax	0 to 12	0.2	4.3	7.1	24.1	20.9	14.1	30.0
Do	13 to 24	.4	7.7	9.7	33.9	24.0	9.1	16.0
Do	25 to 36	.5	7.9	10.3	34.3	24.6	7.1	15.7
Do	0 to 12	.2	4.6	6.8	26.4	22.5	13.4	26.2
Olive orchard, 20 miles north of Sfax	(*)	.3	2.7	3.3	14.9	27.0	22.9	29.3

* Adhering to olive truncheons, probably about 12 inches.

Chemical analyses of a large number of samples of the Sfax olive soils by the chemist of the Tunisian government show them to be very rich in lime (calcium carbonate), of which there is an average of from 5 to 10 per cent. The potash content is also good, the average being 0.1 to 0.2 per cent. On the other hand, they are rather poor in nitrogen (0.03 to 0.05 per cent) and in phosphoric acid (0.04 to 0.05

[a] Bertainchand, l. c.

[b] In the French method of mechanical analysis of soils, much less water is used and the digestion is much more rapid than in the method followed by the Bureau of Soils; consequently by the former method the aggregates of fine particles are less likely to be broken up through the solution of the cementing material.

per cent). According to Trabut,[a] a high lime content is a very favorable factor in growing olives for oil production, as olives produced in limestone regions are richer in oil and the oil is of better quality than where the soils are deficient in this component. It should be noted that while the nitrogen and phosphoric acid content of the Sfax soils would be considered low for most crops, the high yields and good quality of the oil produced at Sfax are sufficient evidence that the supply of these two elements of plant food must be amply sufficient for the requirements of the olive. This can perhaps be explained by the fact that the roots of this tree occupy so great an area of soil (one-seventh to one-tenth acre) that while the percentage of these elements to weight of soil is everywhere low the total amount available to the roots is actually rather high.

THE OLIVE ORCHARDS OF SFAX.

THE VARIETY GROWN.

The Sfax orchards contain only one oil-producing variety, the Chemlaly,[b] to which probably at least 95 per cent of the trees belong, the rest being varieties with larger fruits used for pickling. The fruits of the Chemlaly are very small but are produced in great quantity (Plate III). They are exceedingly rich in oil, yielding 30 per cent in factories where modern presses are used and as high as 34½ per cent in extraction experiments made by the chemist of the Tunis government. These are unusually high percentages, but they are attributable, perhaps, more to the heat of the climate than to a peculiarity of the Chemlaly variety, for still farther south in Tunis the olives are even richer in oil. In the extraction experiments above referred to, olives grown in the celebrated oil-producing district of Bari in southern Italy yielded only 28.2 per cent. In European countries near the northern limit of olive production the fruit is said to yield only 13 per cent of oil.

Oil made from the Chemlaly variety is very pure and of excellent flavor. For commercial purposes, however, it has a serious defect in its high content of stearin, or fixed acid, which causes it to congeal at relatively high temperatures. This characteristic renders Sfax oils difficult to sell in northern Europe, and it is especially prejudicial to their use in preserving sardines, etc. It is not, however, an insuperable objection, since the excess of stearin can be removed at a relatively small expense.

[a] Trabut, L. L'Olivier, Bul. 21, Service Bot., Gouvernm. Gén. Algérie, 1900, p. 43.

[b] Five or six very different varieties, all known as Chemlaly, occur in Tunis. That grown at Sfax is commonly designated as the "Chemlali de Sfax."

Opinions differ as to whether the high stearin content of the Sfax olive oils is a peculiarity of the Chemlaly variety or is due to the character of the soils of Sfax. That it is not attributable to the climate seems certain, for oils made from olives grown in still hotter and drier parts of Tunis are said not to congeal more readily than do those from the northern part of the country. M. Bertainchand, the chief chemist of the Tunis government, holds the character of the soil to be responsible, the soils in which olives are grown in northern Tunis being generally heavier than those of Sfax. It should be noted, however, that oils produced in the oases on the northern edge of the Sahara, where the soils are sandier than at Sfax, resemble the oils of northern Tunis rather than those of Sfax in their percentages of fluid and fixed acids. Perhaps the low water content of the soil contributes to this peculiarity in the composition of Sfax oils, northern Tunis having a much higher rainfall and the oases being abundantly irrigated. The latest authority who has investigated this subject holds, however, that the percentage of stearin is essentially a characteristic of the variety rather than a direct result of the physical conditions.[a]

Whether the large yields of fruit obtained at Sfax from the Chemlaly olive are an inherent characteristic of the variety or are due to the climate or the soil or the superior cultural methods used seems not to be known. All authorities agree, however, that this variety is exceptionally well adapted to growing without irrigation in a hot, dry climate. It has been suggested by Dr. L. Trabut, government botanist of Algeria, that the Chemlaly will probably be useful as a drought-resistant stock upon which to graft larger fruited varieties. It is, in fact, thus employed to some extent at Sfax, but its value for this purpose will probably be limited, since olives that are large enough to be commercially valuable for pickling can in all likelihood be produced only where abundant water is available.

PROPAGATION.

The Chemlaly olive is never grafted at Sfax but is grown on its own roots. It is always propagated by means of large truncheons—pieces of wood taken from the base of the trunk or of the largest roots—a method that seems to be peculiar to Tunis.[b] These cuttings

[a] See Marcille, in Bul. Dir. Agric. et Com., Tunis, 1906, p. 516.

[b] Dr. L. Trabut, the government botanist of Algeria, states that it is not practiced in Algeria. Prof. S. C. Mason, arboriculturist of the Bureau of Plant Industry, reports that the cottonwood (*Populus deltoides*) is sometimes propagated in western Kansas by means of "snags," or truncheons, pieces of wood with several buds obtained by cutting up the branches of this tree. They are of the thickness of a piece of stove wood and 1 or 2 feet long. They are sometimes set in deep furrows and the soil is then firmed in around them.

are obtained from the old neglected trees—relics of the ancient olive orchards—that are scattered over the country (see fig. 2). When such trees do not occur on the estate that is to be planted, the cuttings are purchased from natives who have them. Either the whole tree is uprooted and all the cuttings it can furnish are removed at once with a saw or else only two or three are taken off at a time. In the latter case the usual method is to cut with a hatchet about half way through the root that is selected to furnish the cutting, at two points 8 to 10 inches apart. A spade is then struck into the upper cleft and the root is split down the middle as far as the lower cleft, thus leaving unhurt the under half of the root from which the cutting has been removed. The wounds are carefully trimmed with a pruning knife. In this way the root which furnishes the cutting is left attached to the parent tree and continues its functions.

The truncheons thus obtained are generally 8 to 10 inches long and of very unequal thickness, although said to average 4 inches. The drier the weather and the soil at the time of planting the larger they should be. In no case should they weigh less than 2½ pounds, and they are generally heavier, for the vigor of the tree for the first year or two, at least, depends largely upon the size of the truncheon from which it originates. They retain the bark and should have at least three eyes or buds. If they have roots attached, these are cut off and care is also taken to trim away all rotten wood. The best results are obtained with cuttings taken below the surface of the ground. When of the dimensions just described they will not be injured by exposure for two weeks to the sun and air, but if a longer interval elapses before they are planted they should be wrapped in straw or else buried in the ground until wanted.[a]

CLEARING THE LAND.

The first step in establishing an olive orchard at Sfax is, of course, clearing the land of its native growth of grass and bushes. Where the deep-rooted thorny shrub known as Christ thorn occurs this is

[a] Four dozen such cuttings were imported from Sfax by the Department of Agriculture in 1905. They were taken from the trees about February 15 and were covered with soil until the end of the month, when they were packed with wet straw in ventilated wooden boxes and shipped to New Lork, being watered at least once during the voyage. When unpacked at Washington on April 20, only one or two of them showed signs of life. When planted, however, hardly one failed to send up numerous shoots, which by October 15 had reached a height of 4 to 5 feet. They were sent to San Antonio, Tex., Tucson and Phoenix, Ariz., and several localities in California. In most cases they have made a good growth, and material for further experiments with this variety seems to be assured.

a troublesome and expensive operation, but otherwise a fairly deep plowing is generally effective. As a rule, the greatest difficulty in getting the land clean and keeping it so is due to the presence of Bermuda grass, the worst weed of the Sfax region. As irrigation is not practiced, except that the young trees are watered by hand during the first one or two summers after planting, it is not necessary to level the land. In the largest plantations it is the custom not to clear the entire surface before planting but merely strips about 12 feet wide, in the centers of which the rows of trees are to be set. These strips are broadened from year to year until the whole surface of the orchard has been freed from weeds and brush. Whenever possible, however, it is preferable to clear the entire area at the outset, since the unreclaimed portion harbors Bermuda grass, which rapidly spreads into the strips containing the rows of trees.

PLANTING.

DISTANCE BETWEEN THE TREES.

Wide planting, combined with clean cultivation (see Pls. II and IV), is the chief factor of success in olive culture at Sfax. Fifty years ago the Arabs hit upon the plan of setting out the trees about 80 feet apart each way, thus giving slightly less than seven trees to the acre; but this small number is said to produce as much oil as do 50 trees at Susa or 60 to 80 trees in northern Tunis. The natives continue to plant at this distance, but there is a tendency among the French owners of orchards to decrease the distance between the trees to 65.5 feet, which gives space for 10 trees to the acre if planted in squares and 11½ trees if planted in quincunx, as is now frequently done by French olive growers. This system of wide planting conforms to the habit of the olive tree, at least when grown under the climatic and soil conditions of Sfax. It is there a comparatively shallow-rooting tree,[a] but the roots form a dense network extending horizontally to an average distance, it is said, of 25 feet in every direction. The root systems of two olive trees at Sfax 80 feet apart have been observed to meet.

Great care is taken, even by the natives, to secure a perfect alignment of the trees and to plant them at exactly equal distances. Consequently the Sfax orchards are models of systematic planting.

[a] One olive grower at Sfax informed the writer that practically the entire root system is contained in the first 3 feet of the soil. The shallow-rooting habit of the olive at Sfax may be at least partly due to the method of propagation by truncheons, which prevents the formation of a taproot. Rooted cuttings, such as are used in other parts of Tunis, are said to quickly develop a taproot. There is little doubt, however, that the olive is more shallow rooting than most fruit trees.

TIME AND METHOD OF PLANTING.

The trees are set out from November to February, but the best months are November and December, the benefit of the winter rains being thus secured. When heavy rains occur immediately after planting, as many as 98 per cent of the trees sometimes live, but ordinarily only 80 per cent survive. If the truncheons are set out in November, the shoots appear the following spring. If planting is deferred until February, the shoots do not ordinarily appear until the following autumn, or even the second spring, and the percentage of trees that fail to grow is often very large.

The truncheons are always planted at the bottom of holes (see fig. 4), these being generally 2 feet square and 2—or sometimes 2½—feet deep. The young shoots are thus partially shaded, and the soil around them can be kept much more moist than if the truncheons were planted near the surface of the ground. It is advisable to prepare the holes several months before planting, in order that the soil at the bottom may become thoroughly aërated and be moistened by the first autumn rains. For November planting it is recommended that the holes be made in June or July, since at that time the soil is still moist from the spring rains and hence easy to work. In a light soil a native laborer can dig these holes at the rate of fifty a day.

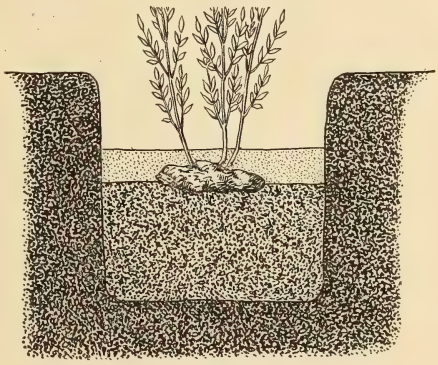


FIG. 4.—Diagram showing method of planting olive truncheons at Sfax. (After Minangoin.)

In planting, the hole is about half filled with loose soil. The truncheon is laid on this, the side on which the bark remains and which contains the buds being of course uppermost. It is then pressed down and covered with about 2 inches of soil. Manure is never put into the hole. As the shoots push up, the hole is filled until, two or three years after planting, it is nearly level with the surface; but it is desirable to maintain a slight depression, in order to hold as much water as possible around the young tree.

Of the numerous shoots that spring up from the truncheons, all are preserved the first year, but during the second year all but the two most vigorous ones are removed, and during the third year only the best and strongest shoot is allowed to grow.

Occasionally the truncheons are planted in nursery form before being set out in the orchard. In a large orchard thus established near Sfax that was visited by the writer, the trees, after having grown one year in the nursery and three years in the orchard, were 5 to 6 feet high above ground. Ordinarily, olive trees grown from these large pieces of old wood begin to bear when six years of age, but do not give any considerable amount of fruit until ten years old.

The estimated cost of planting one hundred trees in the manner above described is $4.75 to $5.30, including the purchase and transportation of the cuttings, digging the holes, and planting. This is only possible because of the very cheap labor obtainable in Tunis, 40 to 50 cents being the ordinary day's wages of laborers in the olive orchards at Sfax.

WATERING THE YOUNG TREES.

While the olive orchards at Sfax are not irrigated after they are once established, sufficient water for that purpose being unobtainable, it is usually necessary to water the young trees during the first summer or two after they are set out. For this purpose the water of wells and cisterns is used. There seems to be much diversity of opinion as to the number of waterings that are necessary, but the usual practice appears to be to water two or three times during each of the first two summers after planting, at the rate of 5 to 10 gallons to the tree at each watering. Frequently the young orchards are given no water during the second summer. In one plantation visited by the writer the trees were watered only once after planting. It is said that in exceptionally rainy years no watering whatever is necessary and that the trees planted in such years make the best growth. The labor required in watering is a considerable item in the expense of establishing an olive orchard at Sfax, the nearest well being often a mile distant from some of the trees.[a] The natives water their trees by means of earthenware jars holding 4 or 5 gallons, but on the large plantations owned by Europeans a watering cart is generally used. To facilitate its passage, a strip of land 6 feet or so wide on either side of the rows of trees is left unplowed during the summer.[b]

[a] Minangoin estimates that there should be one well to every 570 acres of orchard. (L'Olivier en Tunisie, 1901, p. 57.)

[b] As a means of avoiding at least part of this laborious watering, it was suggested to the writer by M. Louis Drappier, of the Service des Antiquités et des Beaux Arts at Tunis, that a practice followed by the Arabs in establishing orchards in parts of Algeria where water is scarce might be advantageously adapted to dry-land olive culture. This consists in placing in the bottom of each hole in which a young tree is to be set about 100 pounds of cactus pads and covering them with a thin layer of soil, upon which the young tree is set. It is said that a supply of moisture sufficient to last two years is thereby assured. It would seem doubtful, however, whether an adequate supply of moisture would thus be provided and also whether good conditions for the roots of the young trees would result from this manner of planting.

TILLAGE.

Good tillage is essential to successful dry-land olive culture as practiced at Sfax, and this was thoroughly appreciated from the beginning by the intelligent natives who brought the present system into general use once more. In order to keep as much moisture as possible in the soil, a dust mulch, which reduces evaporation to a minimum, is maintained on the surface, especially during the summer. This loose condition also facilitates absorption of the rain that falls in autumn, winter, and spring. Furthermore, the greatest care is taken to destroy all weeds that appear. Bermuda grass is the most troublesome of these, much of the land suitable for olive culture around Sfax being thoroughly infested with it. As it is advisable to extirpate this weed before the trees are set out, the best results can sometimes be had when planting is postponed until the second year after work on the orchard is begun. The following method is recommended by Minangoin for getting rid of Bermuda grass.

A shallow plowing—to a depth of only 3 or 4 inches—is given with the rude Arab plow, followed by a harrowing, or preferably two cross harrowings. In this way the soil is pulverized and the grass roots are turned up and exposed to the sun and air. On the other hand, a deeper plowing would only bury the rootstocks out of reach of the teeth of the harrow and the shoots would quickly find their way to the surface again. The land is then gone over with a rake—generally the primitive Arab instrument known as the "messaba"—and the rootstocks gathered up by it are burned. A second, somewhat deeper plowing, followed again by the harrow and the rake, is said to be in most cases effective in extirpating the grass.

A different plan requiring much more time and labor, although equally effective, is generally followed by the Arabs. Instead of the plow they use the "maacha" (see fig. 5), an instrument made like a plow, but having in place of a share a flat, thin bar about 2½ feet long, set so that its front edge slants toward the ground and adjustable so as to cut the soil at the desired depth. It otherwise resembles the native plow and is guided in the same way. This implement is passed over the land at intervals of a week or two, especially in summer, but also a few days after every rainfall in winter and spring. The maacha does not remove the roots but is set so as to cut off the grass stems an inch or so below the surface of the soil. As a result the roots, deprived of leaves, finally rot in the ground. It is sometimes necessary to use the maacha a dozen times in rapid succession before the land is clean. The instrument as used by the natives requires a great deal of strength to operate. The driver must stoop and throw the whole weight of his body against the handle bar; but

an improved form devised by a French colonist at Sfax can be guided by a man standing erect with his hands on the bar.

The importance attached to getting the land clean is shown by the fact that the "m'rharci" contract (see p. 34) is not considered to have terminated until the Bermuda grass has been extirpated. The extraordinary precautions taken to get rid of this weed show how essential clean culture is considered.

After the land has been cleared of weeds, it is worked less often. To obtain the best results, however, it is necessary to plow at least three times every year, irrespective of the age of the trees. The Arab plow, set to a depth of about 4 inches, is generally used. One authority recommends that the first plowing be given in the winter, immediately after the harvest, in order to loosen the soil that has been trampled down in the processes of harvesting and pruning. The second plowing should take place in spring, after the trees have blossomed, and the third in August or September. Many growers, however, omit the plowing in summer, and on some large plantations only a single plowing is given, soon after the harvest is finished. A marked benefit results if the soil is stirred to a greater depth with a French plow once every two or three years. It is considered advisable, however, not to plow deeper than 10 inches, to avoid injury to the roots of the trees. In addition, the maacha is passed over the land, especially after a rain in winter, as often as is necessary to keep down the weeds and restore the mulch. At least three cultivations a year with the maacha are considered essential. The natives as a rule do all their cultivating with the maacha, using the plow only in preparing the land for seeding to grain.

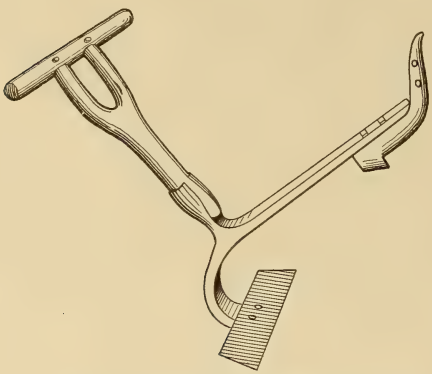


FIG. 5.—The "maacha," the tool used by the Arabs in exterminating Bermuda grass and other weeds. (After Minangoin.)

It is customary during the winter to keep around each tree a shallow basin of the depth reached by the Arab plow. This is at first simply the nearly filled up hole in which the tree was planted, but is extended as the tree increases in size, so as to be always a little greater in diameter than its spread of foliage.

In summer the ground is cultivated up to the bases of the trees, but each autumn the surface of the basins is packed down and made smooth, so as to facilitate gathering the fruit that drops to the ground

during the harvest, which would be hard to pick up from plowed ground. The basins also serve the important purpose of catching and holding rain water around the bases of the trees during the winter and spring. In one plantation visited by the writer there were two short, shallow trenches, converging in V-shape, as shown in figure 6, on the uphill side of each tree, which serve to conduct the surface water after rains to the basin around the tree.[a]

The suggestion was made to the writer by a French tenant on one of the new olive orchards near Sfax that the rain which falls upon the surface of the orchard could be better utilized if only an area around each tree corresponding in extent to that occupied by its roots were cultivated, leaving a strip of smooth, unplowed ground between each two neighboring trees. The water falling on the latter would run off the hard ground between into the cultivated areas around the trees. As a result of the existing practice of keeping the entire surface of the orchard cultivated, all the water is absorbed where it falls, and in the middle of the spaces between the trees, at least while the latter are young, sinks into the ground without reaching their roots. After the trees have reached their full growth, however, it is probable that their root systems occupy practically the entire area of the orchard.

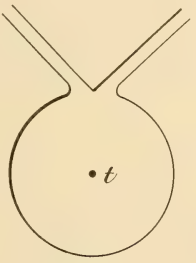


FIG. 6.—Diagram illustrating a method of conducting surface water to the base of an olive tree (*t*).

Until the olive trees begin to bear a considerable quantity of fruit, i. e., usually until they are about ten years old, field crops are frequently grown among them, but after that time, and sometimes after the sixth year, all such crops are rigorously excluded. Barley is the crop that is most often grown in the young orchards, although wheat and horse beans (*Vicia faba*) are also grown. All these are fall-sown crops. Wheat is a more uncertain crop than barley at Sfax and is thought by the natives to draw more heavily on the scanty supply of moisture in the soil. Even barley, though sown every year, can be counted upon to give a good crop only once in three years. In some orchards barley and horse beans are grown in rotation.

From the outset, however, strips of ground 10 to 12 feet wide, in the center of which are the rows of trees, are left absolutely bare. These are widened and the area devoted to small crops is proportionately diminished each year until the olives begin to bear, when the land is left entirely to the trees.

[a] The same practice obtains also in western Algeria. See Trabut, L., L'Olivier, Bul. 21, Serv. Bot. Gouvernm. Gén. de l'Algérie, 1900, p. 41.

MANURING.

Chemical fertilizers are not used at Sfax, and even the application of barnyard manure is rather the exception than the rule, although it is admitted that a marked increase of yield can be obtained by this means. Domestic animals are few in the Sfax region, and in the extensive orchards recently planted by the French on the edge of the olive-growing district manure is often almost unobtainable. Some of the richer natives who own the older orchards near the town are better situated in this respect.

The first application of manure is said to be generally given when the trees are 10 to 12 years old, and thereafter is repeated every four or five years at the rate of 100 to 200 pounds to the tree. The manure is buried near the foot of the tree, the following method of putting it in being recommended by the manager of one of the large French plantations: A trench about 6 feet long, 2 feet wide, and 2 feet deep is dug on the uphill side of the tree, about 6 feet distant from its base, and is filled with well-rotted mixed barnyard manure. Formerly the manure was buried around the tree at its very foot, a practice that frequently injured the bark of the crown.

PRUNING.[a]

One can not visit the older olive orchards around Sfax without being impressed by the symmetry of the trees and the uniformity in size and shape of their tops. This regularity is due to the great care that is given to the matter of pruning. Certain of the natives who are adepts at this work and can prune on an average eight or ten trees a day receive 60 cents a day for their services. The cost of pruning is partly and sometimes fully covered by the value of the wood removed in the process, firewood being scarce and dear in that region. The larger branches are removed with a saw and the smaller ones with a pruning hook, care being taken to make clean sections.

From the time the trees are three years old until they begin to bear they are trimmed a little every year, just enough to give them the proper shape. Severe pruning of the young trees is avoided, as it interferes with the proper development of the root system, upon which so much depends in the dry climate of Sfax. During the first two or three years it is considered inadvisable to prune the root shoot that has been selected to form the trunk, as otherwise it will grow up rapidly into a spindling, little-branched stem. When the tree is three years old the terminal shoot is cut off, and the first four

[a] Much of the information contained in this section is taken from Minangoin, N., L'Olivier en Tunisie, Tunis, 1901, a publication that has been freely consulted in preparing the chapters on cultural methods.

branches below it are allowed to develop, all branches farther down the stem being suppressed (fig. 7). It is said that bearing commences on an average two years earlier when the terminal shoot is removed than when it is allowed to remain. The removal of the apex of the stem causes the four branches that are left just below it to ascend obliquely instead of spreading horizontally. The year following the tips of these four branches are in turn removed and all but one of their lateral twigs are cut back (fig. 8). During the fifth year new twigs begin to shoot out from the buds on the stumps (fig. 9) and the young tree begins to assume definite form.

FIG. 7.—Sketch showing the proper form to give in pruning a three-year-old olive tree. The dotted lines indicate the branches that are removed. (After Minangoin.)

The pruning is directed so as to secure a symmetrical, well-rounded top (Pl. I and Pl. IV, fig. 2) with the leading branches at regular intervals and rather far apart. Care is taken to prevent the tree from becoming so tall as to make harvesting difficult, the ideal being a height that equals the spread of the foliage. The inner branches are kept well thinned out, so as to insure the access of as much light as possible to all the fruit-bearing twigs. The rapidly growing erect shoots, which absorb much of the sap of the tree and bear little or no fruit, are removed, except those that are destined to become the main branches. Branches growing in a horizontal direction or inclined to droop at the end are favored. The yield largely depends upon the attention given to these points. The superiority in size of trees and the greater magnitude and regularity of yield shown by the Sfax orchards as compared with those of other parts of Tunis are largely attributed to the care with which the pruning is done.

FIG. 8.—The tree shown in figure 7 as pruned when four years old. (After Minangoin.)

When the trees begin to bear, biennial pruning is generally substituted for annual, and the operation is usually performed immediately after the harvest, in January or February. On some plan-

tations, however, the trees are pruned lightly every year, and this is said to insure larger yields year in and year out and to cause less injury to the trees. In annual pruning, the custom is to prune lightly after a small crop in order to secure a heavy crop the season following. After a good crop a thorough pruning is given, as the same tree will not yield heavily two years in succession.

HARVESTING.

Olives commence to ripen at Sfax in October, those borne by the youngest trees being the first to mature. The harvest ordinarily begins in the latter part of October and lasts until the end of January, but when the crop is unusually heavy it sometimes continues until March or even April. The fruit is mostly sold on the tree, the buyer taking charge of the harvest. In this, as in all operations connected with olive growing, greater care is taken at Sfax than in most olive-producing regions. The harvester by means of a double ladder (see Pl. I, frontispiece) is able to gather most of the fruit by hand. The use of a pole is avoided as far as possible, since the olives are likely to be injured by bruises when knocked off. Moreover, many of the young twigs, which are to bear the crop of the following year, are destroyed when this method is followed. In pruning, the importance of making every part of the tree as accessible as possible to the harvester with his ladder is taken into consideration.

FIG. 9.—The tree shown in figures 7 and 8 as it appears when five years old. (After Minangoin.)

The natives are very dexterous in gathering the fruit, holding the branch with the left hand and stripping it with the right, three fingers of which are armed with the tips of rams' horns, worn like thimbles. The fruit is stripped off into a basket which is fastened to the ladder. When full, the basket is lowered to the ground by means of a cord. It is then emptied by the women upon pieces of cloth or matting, and the fruit is freed from the débris of leaves, twigs, etc., mixed with it. Finally the olives are packed into large panniers, two of which make up a camel load (450 pounds). In the evening or

very early in the morning these baskets are loaded upon camels and are thus transported to the factory. When received there they are placed in shallow cement tanks without covers and are left exposed to the weather for three or four days. This renders them soft and permits the extraction of the oil with much less pressure than is required when freshly gathered fruit is put into the presses.

The olives are sold both in the orchard and at the factory at so much the "kaffiz," an Arab measure containing about 136 gallons. The ordinary price paid per kaffiz at the factory is $13 to $15, which is an advance of 10 to 20 per cent on that paid for fruit on the tree. The price of a kaffiz of olives varies as much as $4 during a single season. In 1899 it rose to $20, and even $22, at the factory.

YIELDS OBTAINED.

The rapidity with which the orchards come into bearing depends largely upon the thoroughness of the cultivation given them and the degree of skill used in pruning. While well-tended trees sometimes bear a little when only 3 years old, neglected trees do not begin to yield until they are 12 or 15 years old. As a rule it is eight to ten years from the time of planting before any considerable quantity of fruit is produced. Well cared for trees that are 10 years old are considered to be worth $3 to $3.50, the value increasing to from $5.70 to $7.60 for trees 15 years old and from $9.50 to $13.30 for trees 25 years old. When they reach the age of 25 years the trees are generally in full bearing. According to one authority, however, the yields continue to increase up to the age of 40 years. Minangoin [a] gives the quantities of fruit and of oil from trees of different ages as follows:

TABLE IV.—*Average yields of fruit and of oil from olive trees of different ages in the orchards of Sfax.*

Age of tree.	Yield of fruit.	Yield of oil.	
		Percentage of weight of fruit.	Absolute quantity.
Years:	*Gallons.*	*Per cent.*	*Gallons.*
8	5.3	15	0.8
10	10.6	15	1.6
15	15.9	20	3.2
20	21.2	25	5.3

It is evident from the data given in Table IV that not only the total yields of fruit and oil but the percentage of oil to fruit by

[a] Minangoin, N. Culture de l'Olivier * * * dans le Centre de la Tunisie, Tunis, 1900, p. 16. In the original the quantities are of course given in liters, not gallons.

weight increase rapidly with the age of the tree. When 25 years old, the average yield of oil per tree is about 6 gallons. Some individual trees attain a production of over 50 gallons of fruit, but such heavy bearers are said to constitute not more than 1 or 2 per cent of the Sfax orchards.

After the trees have come into full bearing their yields are said to remain stationary until they are 50 years old, when their productiveness begins to decline. When 80 years old the yields are said to diminish and become very irregular, dwindling to almost nothing in trees a hundred years old. If thoroughly pruned, cultivated deeply enough to lay bare the roots, and well manured, however, old trees can again be brought into bearing.

The crop at Sfax from trees over 20 years old is said to be worth on an average about $2, although sometimes attaining from $3 to $4 per tree. It must be remembered, however, that there are only seven to ten trees to the acre.

It is instructive to compare the yields given in Table IV with those obtained in other olive-growing countries. Thus, in Provence, in southern France, well cared for trees in full bearing are said to produce an average of only 3.9 to 5.3 gallons of fruit, which, if we take the percentage of oil to be about half what it is at Sfax, would give about 0.6 gallon of oil. Hence, although in Provence the trees are planted only 33 feet apart, which allows about 60 to the acre when in squares and 70 when in quincunx, the yield of oil to the acre from well-tended orchards would still fall short of that at Sfax.

The olive is markedly periodic in its bearing and will not produce two heavy crops in succession, no matter how favorable the climatic conditions may be. At Sfax the rule is said to be that if a tree yields heavily one season it will give a medium crop the second and a light crop the third season following. Different trees yield heavily in different years, so that every year some trees are giving their maximum crop.

In January, 1900, there were in operation at Sfax 28 oil mills operated by steam power and 48 native mills operated by animal power. There were 15 mills controlled by Europeans and equipped with modern machinery. The total number of presses was 155, of which 56 were run by steam and 99 by animal traction.

RELATION OF RAINFALL TO YIELDS.

It is interesting to compare the amount of rainfall with the character of the olive crop at Sfax during each of a series of years, such a comparison being given in Table V and being shown also in figure 10.

TABLE V.—*Yearly rainfall and olive production at Sfax in the years 1895 to 1904, inclusive, the latter being indicated by the exports of olive oil from the port of Sfax during each following year.*

Year.	Total rainfall.	Olive crop of the year.[a]	
		Quantity.	Proportion of the average yield.
	Inches.	*Gallons.*	*Per cent.*
1895	3.18		
1896	10.53	627,980	94.0
1897	12.92	706,625	106.0
1898	6.75	983,360	148.0
1899	5.57	523,258	78.5
1900	4.13	612,711	92.0
1901	7.93	253,120	38.0
1902	4.58	1,022,980	153.5
1903	5.26	591,985	89.0
1904	6.77	666,386	100.0
Average for 10 years	6.44	665,368	100.0
Normal for 16 years	9.35		

[a] It should be noted that the statistics of exports do not discriminate between oil produced by the crop of the preceding autumn and that of two years previous, some part of which is sometimes held in reserve at Sfax if the market be dull. However, a comparison of the average prices of olive oil at Marseille with the volume of the annual exports from Sfax furnishes no evidence that the price is the chief factor in determining the quantity exported each year. It is also uncertain to what extent the coming into bearing of the recently planted orchards may affect the figures, although presumably the addition thus made to the total production has been a gradual one and not likely to cause marked fluctuations. In the main, therefore, it is believed that the above figures are fairly representative of the annual crop. To arrive at the total annual production of oil by the Sfax orchards we must add to the figures in the column showing quantity produced, 531,700 gallons, representing the average amount that is consumed locally or shipped overland to other parts of northern Africa. This is said to vary little from year to year.

Although the records do not cover a sufficiently long period to establish a definite relation, it would appear that there is some connection between the size of the crop and the amount of rainfall of the

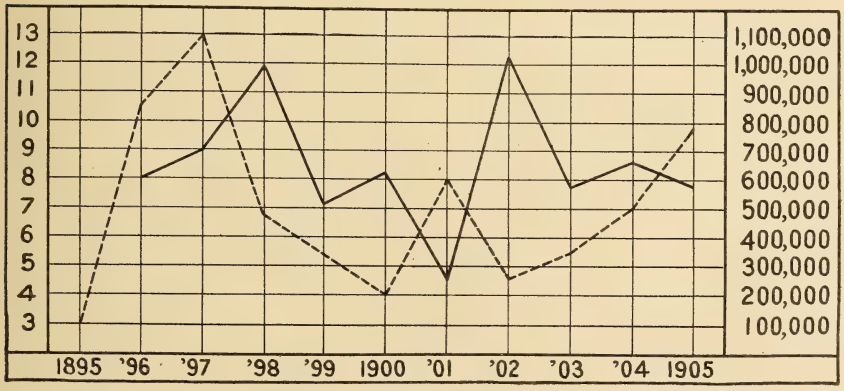


FIG. 10.—Chart showing the rainfall in inches (dotted line) and the production of olive oil (solid line) at Sfax from 1895 to 1905, the oil production being expressed in number of gallons exported during each following year.

preceding year or years, but not that of the spring preceding the ripening of the crop. Thus, the comparatively heavy rainfall (3.6

inches above the normal) in 1897 doubtless had something to do with the large crop of 1898, although the total rainfall of the first five months of the latter year was less than half of the normal. Again in 1901, when the crop was less than half the average of nine years, the rainfall for the first five months was not greatly below the normal, but that of the year previous was less than half the normal, and during the three years previous the annual rainfall was only a little more than half the normal. It is noteworthy that in 1900, after two years of rainfall much below the normal, the crop was about an average one. This was probably due to the heavy rainfall of November, 1899, which was more than three times the normal for that month, while the precipitation during the first five months of the year in which the crop was made was less than 40 per cent of the normal.[a]

That successful olive culture without irrigation is possible with even a smaller rainfall than the normal for Sfax is indicated by the fact that the oil production of 1903 was only a little below, and that of 1904 was slightly above, the average, although following periods of five and six years, respectively, during which the total annual rainfall was only about 60 per cent of the normal.[b]

LABOR.

While some of the French owners of olive orchards near Sfax manage their own plantations directly or through foremen, the majority have found it more convenient, and until very recently more economical, to follow the practice of the native proprietors and enter into contracts with tenants, or "m'rharcis." The latter are natives more or less skilled in olive culture who undertake the planting and care of the trees. It was formerly customary to terminate the agreement between the proprietor and the m'rharci when all gaps in the orchard had been filled by replanting, all Bermuda grass had been extirpated, and the trees were beginning to bear, which was generally accomplished eight years after the planting. It is now more usual to continue the agreement until the trees begin

[a] After this bulletin was in type, a report was received that the total exports of olive oil from Sfax in 1906 (crop of 1905) amounted to 592,000 gallons, which was below the average for the preceding ten years. This is doubtless to be explained by the small rainfall of the years 1902 to 1904, which averaged only about 60 per cent of the normal. On the other hand, the total rainfall in 1905 was 9.9 inches.

[b] This may have been partly due, however, to the rapid extension of the orchards during the past twenty years having begun to make itself felt through the increase in the number of bearing trees. It is to be regretted that no data are available which would throw light on the influence of this factor as compared with that of annual variations in the rainfall.

to bear sufficiently to pay the current expenses of the orchard, i. e., for about ten years. At the expiration of the contract the m'rharci receives in remuneration for his services one-half of the area planted. This arrangement has the advantage of retaining in the neighborhood a number of skilled laborers upon whom the proprietor can generally depend for the care of his part of the trees after the contract has terminated.

The division of the trees between the proprietor and the m'rharci is made by drawing lots, under the supervision of the amins, who act as agricultural magistrates, and whose duty it is to settle disputes between employers and employees.[a] It is said that the amins, although themselves always natives, are generally fairly impartial in regulating differences between Europeans and their m'rharcis. The proprietor generally seeks to have the plantation divided in such a way that the holdings of his former tenants will be scattered among his own. Many of the m'rharcis prefer, however, to receive money for their share of the trees.

At the beginning of the contract a sum amounting generally to 30 or 40 cents for each tree is advanced by the proprietor, to be used by the m'rharci in purchasing the necessary animals, tools, etc. The loan, which bears no interest, is repaid when the agreement ends, usually in trees from the m'rharci's share. The proprietor furnishes the land, while the m'rharci contributes the truncheons that are planted, the tools and animals used, and all the labor required in clearing, planting, and cultivating. A single m'rharci generally plants and cares for from 150 to 300 trees, while if he has a family to aid him he can sometimes handle as many as 600. He requires one camel for plowing and cultivating every 25 acres. The entire product of the field crops grown in the orchard during the first few years is the property of the m'rharci, unless, as often happens, the proprietor furnishes one-third of the seed used, in which case he is entitled to from one-fourth to one-third of the crop. It is estimated [b] that under this system it costs about $1.40 per tree to set out an olive orchard and care for it until it is 10 years old.

Until recent years, decidedly better results were obtained under the contract system above described than when the proprietor directly or through a European foreman undertook to establish an orchard; but the former method is becoming every year more expensive. Many of the best native growers now have trees of their own to care for and are no longer willing to bind themselves out as m'rharcis. The m'rharci no longer finds on the land to be planted an abundance of old trees from which truncheons can be obtained, and these must

[a] See Bul. 92, Bureau of Plant Industry, p. 32.

[b] Minangoin, N. L'Olivier en Tunisie, Tunis, 1901, pp. 59 and 68.

frequently be purchased for him by his employer. Furthermore, the m'rharci now expects his employer to advance him 40 cents or more instead of 20 to 30 cents per tree at the beginning of the contract.

But, notwithstanding the increasing expense, the contract system still has decided advantages. Europeans who have planted and cared for orchards by hiring laborers under their direct supervision rather than by contracting with a m'rharci have generally found their expenses heavier and the work—especially that of getting rid of weeds—less efficiently done. Besides, they lose the advantage of having around them, when their trees begin to bear, a number of their former m'rharcis, skilled and trustworthy men with whom they have been accustomed to deal and who are usually willing, for moderate wages, to continue the cultivation of their old employer's orchard as well as of their own.

Some of the large plantations belonging to nonresident Europeans are managed by a French agent or foreman under contract for a certain period (generally ten years). He receives a small salary ($30 or $40 a month) and is entitled, at the expiration of his contract, to a certain percentage—usually one-eighth or one-tenth—of the land planted in olives. He in turn either hires laborers or else contracts with native tenants or m'rharcis for the planting and cultivation of the orchard. It is said that an orchard established under the supervision of a competent foreman will yield sufficient fruit after eight years to pay all or most of the running expenses.

The cultivation of the orchard after the m'rharci contract has expired is carried on either by reengaging the m'rharci, in which case he receives one-third or one-half of the crop produced, or else by hiring day laborers. In the latter case it usually costs the owner 18 cents per tree annually to have the cultivation and pruning done. If paid by the day, a laborer earns from 40 to 50 cents when engaged in cultivating or plowing. With a camel he can plow 2½ acres in two or three days and can cultivate the same area with a "maacha" in one day. For pruning, which requires special skill, a man receives about 60 cents a day. The crop, as we have seen, is generally gathered under contract by the purchaser, the harvesters being usually paid with a share of the fruit.

UTILIZATION OF THE RUN-OFF IN OLIVE CULTURE IN OTHER PARTS OF TUNIS.

Olive orchards occupy large areas in northern Tunis, notably in the neighborhood of the capital itself and in the valley of the Mejerda, the principal river of Tunis. In this region the annual rainfall [a] is sufficient for olive production without any special meas-

[a] The average annual rainfall at the city of Tunis is 18.8 inches.

ures being taken to conserve the soil moisture. The olive is also an important tree in some of the oases of southern Tunis, where the scantiness of the rainfall [a] is compensated for by the abundant supply of water from springs that is available for irrigation.

But in one of the most important olive-producing regions in Tunis, i. e., that surrounding Susa [b] on the eastern coast, the normal annual rainfall of 16.6 inches, although greatly exceeding that at Sfax, is yet so small as to make it worth while to employ a special method for utilizing it to the fullest possible extent. This method is very different from that used at Sfax, and in its way is almost equally interesting. The country around Susa is very hilly, being divided by limestone ridges into small valleys and ravines. The bottoms of these valleys and the lower slopes, which are made sufficiently level for the purpose by a system of terracing, are occupied by small basins, separated one from another by low banks of earth. Each basin contains a few olive trees, usually only from two to eight. The stony upper slopes and summits of the ridges, which produce a scanty natural growth of shrubs and grasses, are not cultivated. At intervals along these slopes, or "meskas," as they are termed by the Arabs, are shallow trenches running obliquely toward the bottom. These are so arranged as to catch and conduct to the basins as much as possible of the rain water that falls upon the slope. The owner of each orchard has a recognized right to all water that falls upon the slopes adjacent to his property. The basins are said often to remain filled with water during the month of January.

The heavier texture of the soil around Susa as compared with that at Sfax is favorable to this method of irrigation by rainfall, as it permits the water to flow from basin to basin, instead of being all quickly absorbed in the first one. It is generally observed in this region that olive orchards that are watered by the rain that falls on the "meskas" give larger and especially more regular yields than those receiving only direct rainfall.

From the nature of the case, accurate alignment and widely distant planting of the trees as practiced at Sfax are out of the question at Susa. The trees stand comparatively close together, so that there are often forty to the acre instead of only seven to ten, as at Sfax. Much less care is taken to cultivate the soil, and this also is more or

[a] The normal annual rainfall in the oasis of Gafsa is 8.5 inches; in that of Gabes, 7.6 inches; in that of Tozer, 5.1 inches. In the oasis of El Oudiane, 9 miles distant from Tozer (see Bulletin 92, Bureau of Plant Industry, p. 16), there are 25,000 olive trees, with an average yearly production of 132,000 gallons of oil.

[b] Susa, better known by its French name of Sousse, is about 70 miles southeast of Tunis and about an equal distance north of Sfax.

less inevitable from the nature of the ground; but there seems to be no good excuse for the small attention that is paid at Susa to pruning, as compared with the thoroughly scientific way in which this operation is performed in the Sfax orchards.

Many of the trees have several trunks, which is explained by the natives as having been due to a violent storm, which a century ago laid low most of the olive trees around Susa, after which event several shoots at the base of each tree were allowed to spring up.[a] The greater part of the olive trees around Susa are of great age, often 100 or 150 years old, it is said. But when well cared for with respect to cultivation of the soil, pruning, and manuring, even these old trees are reported to give good returns, netting the owners in some years as much as 95 cents to the tree, or $38 per acre.[b]

SUMMARY.

(1) Arboriculture is an important phase of dry-land agriculture and one that has as yet received little attention in the United States.

(2) The olive, owing to its peculiar leaf structure and to the character of its root system, is especially fitted for growing in regions where the rainfall is slight and irrigation is impossible.

(3) Fifteen hundred years ago the olive was grown without irrigation under a rainfall of from 8 to 14 inches over an extensive region in northern Africa, the prosperity of which in Roman times depended chiefly upon its production of olive oil. A vast region that is now practically an uninhabited desert was then covered with olive orchards and with flourishing cities and towns.

(4) During the last hundred years much progress has been made in reestablishing dry-land olive culture in southern Tunis. There are now nearly 500,000 acres of unirrigated olive orchards in the neighborhood of Sfax.

(5) As would be expected from its nearness to the Sahara, the climate of Sfax is almost desert-like. The summers are very hot and the average annual rainfall is only 9.3 inches, sometimes falling below an average of 6 inches for seven consecutive years. As in California, the summer is the dry season and the winter the wet season.

(6) The ground water lies too deep to be reached by the roots of the trees. No water is available for irrigation.

(7) The soil of the Sfax region that is considered best adapted to olive culture is a red loam or fine sandy loam that is fairly uniform in texture to an average depth of seven feet. It is very retentive of moisture, rich in lime and potash, but apparently deficient in nitrogen and phosphoric acid.

[a] Minangoin, N. L'Olivier en Tunisie, Tunis, 1901, p. 32.

[b] Minangoin, N., l. c., p. 54.

(8) Only one variety of olive, the Chemlaly, a small-fruited oil-producing variety, is extensively grown in the Sfax region. It is a very productive variety and its fruits yield an unusually high percentage of oil.

(9) Wide planting and thorough cultivation are the most important principles of olive culture at Sfax. The trees are planted 65 to 80 feet apart in each direction, giving space for only seven to ten trees to the acre.

(10) The olive is propagated at Sfax by means of large truncheons or pieces of old wood, each containing several buds. These are set to a depth of about a foot in holes, which become gradually filled as the young trees grow up. During the first summer or two, two or three waterings by hand are usually given. All shoots but the best one are trimmed away within three years after setting out the truncheon.

(11) A good dust mulch is always maintained on the surface of the orchard, and weeds, of which Bermuda grass is the most troublesome, are kept down by frequent cultivation. As a rule, the soil is stirred by a shallow plowing three times a year. The most important plowing is the one that immediately follows the harvest. After the trees begin to bear, no other crop is allowed to grow among them.

(12) Great care is taken in the matter of pruning, the trees being given a broad, symmetrical top. The interior branches are thinned out so that plenty of light and air can reach all the fruit-bearing twigs. The comparatively sterile, rapidly growing, erect branches are removed. Skillful pruning is an important factor in the large yields obtained.

(13) The harvesting is done by hand, more than usual care being taken to avoid bruising the fruit or breaking the branches.

(14) After eight or ten years the trees generally yield enough fruit to pay the current expenses of the orchard, and when about 25 years old they are in full bearing. The average yield per tree is then about 24 gallons of fruit, which gives 6 gallons of oil.

(15) There is apparently a relation between the yield of the olive and the rainfall of the previous year, but none between the yield and the rainfall of the year in which the crop is made.

(16) In another part of Tunis, where the rainfall is about 16.5 inches and the country more hilly than around Sfax, the rain that falls on the slopes is collected in trenches and conducted into small basins in which the trees are planted.

PLATES.

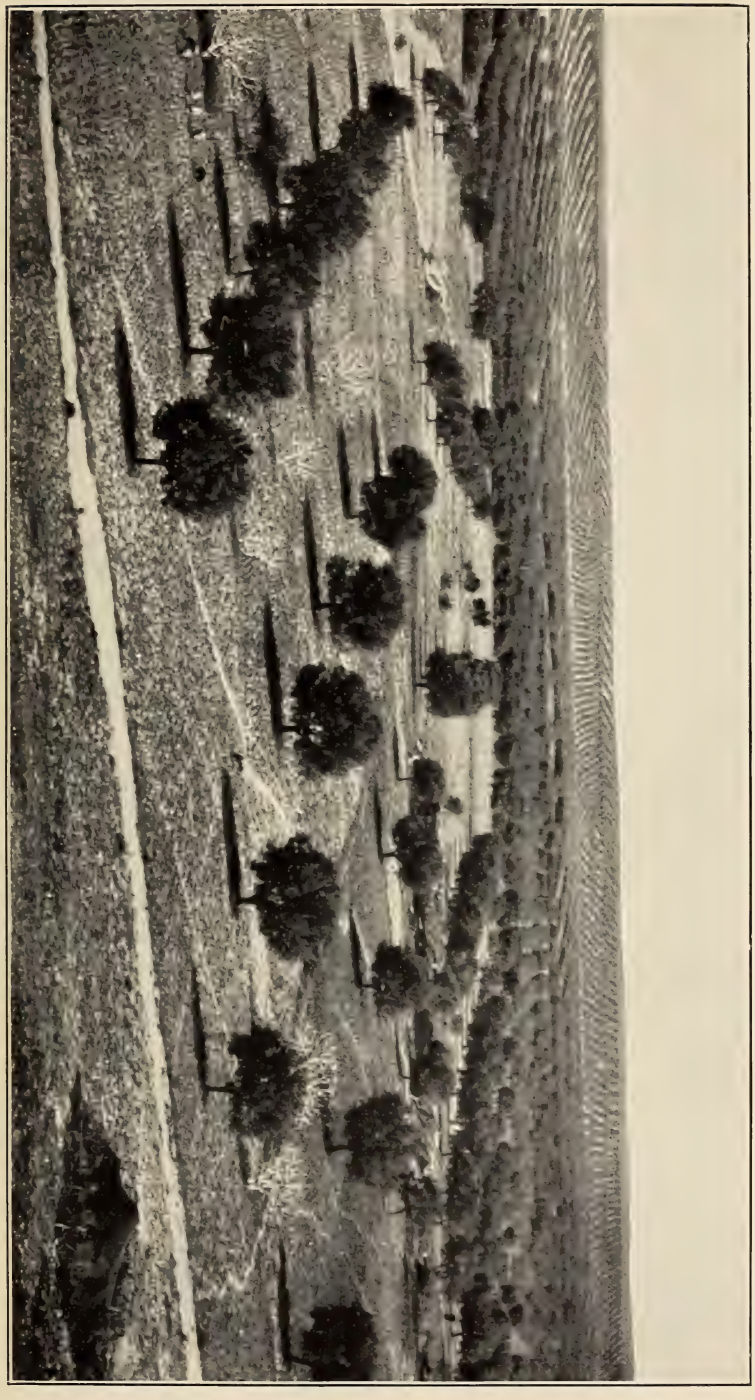
DESCRIPTION OF PLATES.

PLATE I. *Frontispiece.* Harvesting Chemlaly olives in a dry-land orchard at Sfax in southern Tunis. Since the quality of the oil is impaired if the fruit becomes bruised, the use of a pole is avoided and the picker uses a ladder to reach the fruit-bearing twigs. Pruning is managed so that every part of the tree can be reached in this way. The native pickers protect their fingers with the tips of rams' horns and can thus strip the fruit off the twigs without injuring their hands. The olives are collected in the large baskets shown in the illustration and are transported by camels to the factory. The plate also shows the clean cultivation of the orchards, the dust mulch maintained on the surface, and the care with which pruning is done.

PLATE II. General view of the older dry-land olive orchards near Sfax, showing the wide planting and clean cultivation practiced and the uniform shape given the trees by careful pruning. The leafless trees in the foreground are figs, these and other fruit trees being occasionally planted in the olive orchards that belong to natives. (From a photograph furnished by the Direction des Antiquités et Beaux Arts at Tunis.)

PLATE III. A fruit-bearing twig of the Chemlaly olive, natural size, from a photograph by M. Minangoin. The fruits of this variety are small but numerous and are very rich in oil. They are jet black when ripe.

PLATE IV, Fig. 1.—Recently planted dry-land olive orchards about twenty miles from Sfax. The view shows the careful alignment and wide spacing of the trees, which are 80 feet apart each way and number only 7 to the acre. Most of the trees shown are from ten to twelve years old. The hillside in the immediate foreground and that in the left background are unfit for planting to olives because of the absence of soil, a calcareous rock coming to the surface at these points. Fig. 2.—The interior of an older olive orchard at Sfax, showing the entire absence of weeds, the great distance between the trees, and the well-rounded symmetrical form of the trees due to scientific pruning. These trees are about thirty years old and are in full bearing.



GENERAL VIEW OF THE OLDER DRY-LAND OLIVE ORCHARDS NEAR SFAX.

A FRUIT-BEARING TWIG OF THE CHEMLALY OLIVE.

(Natural size.)

FIG. 1.—RECENTLY PLANTED DRY-LAND OLIVE ORCHARDS NEAR SFAX, SHOWING THE CAREFUL ALIGNMENT AND WIDE SPACING OF THE TREES.

FIG. 2.—THE INTERIOR OF A SFAX OLIVE ORCHARD, SHOWING WIDE PLANTING, CLEAN CULTIVATION, AND CAREFUL PRUNING.

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